

The STAR W Program : New Results and Future Measurements

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Abstract. The production of W^\pm bosons in longitudinally polarized p+p collisions at RHIC provides a new means of studying the spin-flavour asymmetries of the proton sea quark spin distributions. Details of the W^\pm event selection through the e^\pm decay channel at mid-rapidity are presented, along with preliminary results for the production cross section and parity-violating single-spin asymmetry, A_L , from the STAR Collaboration's 2009 data set at $\sqrt{s} = 500$ GeV. Lastly, the expected sensitivities for future running are discussed.

1. Introduction

High-energy polarized p+p collisions at $\sqrt{s} = 500$ GeV at RHIC provide a unique way to study the partonic spin structure of the proton. Inclusive polarized deep-inelastic scattering (DIS) experiments have shown that only $\sim 30\%$ of the spin of the proton is attributable to the polarization of the quarks [1]. However, these inclusive measurements do not discern between the various flavours of the quarks and their individual contributions. Semi-inclusive DIS measurements, however, can achieve separation of the quark and anti-quark spin contributions by flavour [2]. The extracted anti-quark polarized Parton Distribution Functions (PDFs) have sizable uncertainties compared to the well-constrained quark and anti-quark sums [3].

$W^{-(+)}$ bosons are produced in p+p collisions, at leading order, through $\bar{u} + d(\bar{d} + u)$ interactions at the partonic level and can be detected through their leptonic decays. The parity-violating nature of the weak interaction gives rise to large single beam helicity asymmetries, A_L , which yield a direct and independent probe of the quark and anti-quark polarized PDFs. The single helicity asymmetry is defined as $A_L = (\sigma^+ - \sigma^-) / (\sigma^+ + \sigma^-)$, where $\sigma^{+(-)}$ refers to the cross section when the helicity of the polarized proton beam is positive (negative). Theoretical frameworks have been developed to describe the production of W^\pm bosons and their decay leptons in polarized p+p collisions [4, 5].

2. Recent Measurements

The measurements described in these proceedings were done using the STAR detector [6] at RHIC. The used detector systems are the Time Projection Chamber (TPC), which provides tracking of charged particles in a 0.5 T solenoidal magnetic field for pseudorapidities of $|\eta| \leq 1.3$ and the Barrel and Endcap Electromagnetic Calorimeters (BEMC,EEMC), which are lead-scintillator sampling calorimeters covering $|\eta| \leq 1$ and $1.09 \leq \eta \leq 2$, respectively. All three detectors provide 2π coverage in azimuthal angle, ϕ . The data presented in this contribution, which correspond to 13.7 ± 0.3 (stat) ± 3.1 (syst) pb^{-1} of sampled luminosity, were accumulated in 2009 when a first significant dataset was collected for polarized proton collisions at a centre

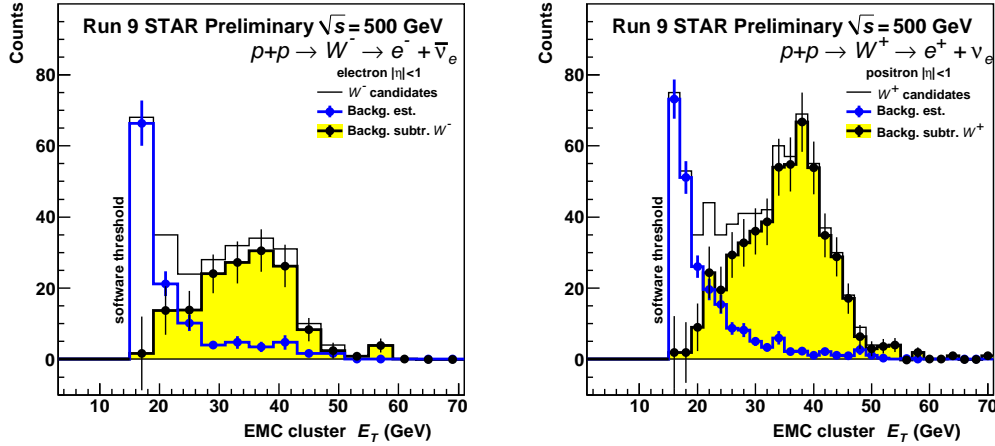


Figure 1. The charge separated W^\pm candidates distributions (black), the estimate of the background (blue) and the extracted signal (yellow).

of mass energy of $\sqrt{s} = 500$ GeV. During this period, the beam polarizations averaged $(38 \pm 3)\%$ and $(40 \pm 5)\%$ for the two beams.

In this analysis, only the $W^\pm \rightarrow e^\pm + \nu$ decay channel was considered. The electrons and positrons at mid-rapidity from these W^\pm decays can be detected by a large transverse energy, E_T , peaked near $M_W/2$. In order to preferentially select the events containing a high energy e^\pm , a two-stage online BEMC trigger was required. First an event was required to satisfy a hardware threshold corresponding to a transverse energy, $E_T > 7.3$ GeV, in a single BEMC tower. Additionally, a software level trigger then searched for a seed tower with $E_T > 5$ GeV and required that the maximum 2×2 tower cluster including that seed have an E_T sum larger than 13 GeV.

W^\pm candidate events were selected offline based on kinematical and topological differences between leptonic W^\pm decay events and QCD background (e.g. di-jets) events. $W^\pm \rightarrow e^\pm + \nu$ decay events contain a nearly isolated e^\pm and an undetected neutrino opposite in azimuth, leading to a large missing E_T . The selection proceeded in three stages : e^\pm candidate identification, isolation, and background rejection. An e^\pm candidate is identified as any TPC track with $p_T > 10$ GeV/c which originated from the event vertex with $|z| < 100$ cm, where z is the direction along the beamline from the nominal interaction point. Furthermore, it was required that this track points to a 2×2 BEMC tower cluster with an E_T sum, $E_T^{2 \times 2}$, greater than 15 GeV and whose centroid was less than 7 cm from the extrapolated track. Next, two isolation cuts are imposed on the candidate. First, successful candidates were required to have an excess E_T in the surrounding 4×4 tower cluster be less than 5% of $E_T^{2 \times 2}$. Secondly, the candidates were required to have an excess EMC tower + TPC track E_T sum of less than 12% of $E_T^{2 \times 2}$ within a cone radius $R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.7$ of the candidate. Two background rejection cuts were applied. First, the magnitude of the vector p_T sum of the e^\pm candidate p_T vector and the p_T vectors of all the reconstructed jets with thrust axes outside the $R = 0.7$ cone around the candidate was required to be greater than 15 GeV/c. The jets were reconstructed using the standard mid-point cone algorithm used in previous STAR jet measurements [7, 8]. Second, the away-side E_T , which was defined to be the EMC + TPC E_T sum over the full range in pseudorapidity and having $\Delta\phi > 3\pi/4$ from the e^\pm candidate track, was required to be less than 30 GeV.

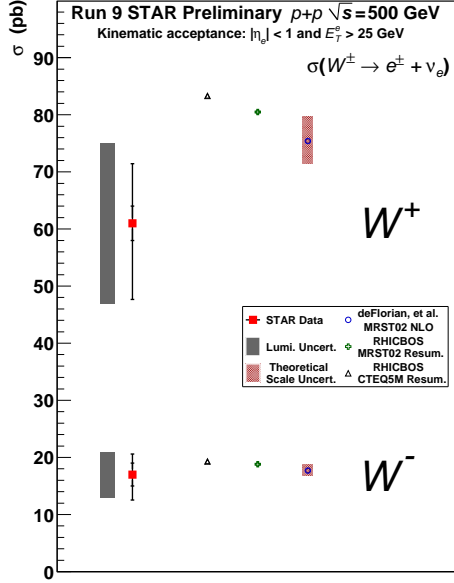


Figure 2. The extracted cross sections for $W^\pm \rightarrow e^\pm + \nu$ in proton-proton collisions at $\sqrt{s} = 500$ GeV. Also plotted are theoretical expectations [4, 5] for a variety of PDFs.

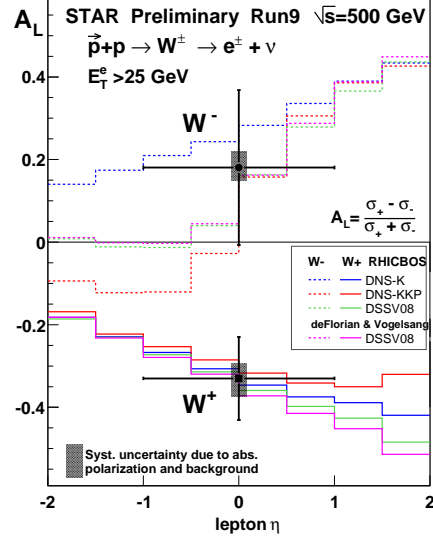


Figure 3. The extracted single helicity asymmetries for $W^\pm \rightarrow e^\pm + \nu$ in polarized proton-proton collisions at $\sqrt{s} = 500$ GeV. Also plotted are theoretical expectations [4, 5] for a variety of polarized PDFs.

After these cuts were applied, the W^\pm candidates (see figure 1) show the characteristic Jacobian peak at $E_T^{2 \times 2} \sim M_W/2$. The amount of background remaining in the W^\pm candidate sample, after applying the selection criteria described above, was estimated from three contributions. The first contribution was from $W^\pm \rightarrow \tau^\pm + \nu$ decay where the τ^\pm decays semi-leptonically to an e^\pm and two neutrinos. This background was estimated using Monte Carlo simulation. Another contribution estimated the impact of the missing calorimetric coverage for $-2 \leq \eta \leq -1.09$. To determine this contribution to the background, the analysis was performed a second time with the EEMC not used as an active detector. The difference in the W^\pm candidate $E_T^{2 \times 2}$ distribution with and without the EEMC included in the analysis was taken to be the estimate for the missing calorimetric coverage. The third contribution was estimated by normalizing a data-driven background shape to the remaining W^\pm candidate signal, in the $E_T^{2 \times 2}$ range below 19 GeV, after the first two background contributions were removed. This data-driven background shape was obtained by inverting the last two requirements in the W^\pm candidate selection, namely by requiring that the away-side E_T be greater than 30 GeV or the magnitude of the vector p_T sum be less than 15 GeV/c. The total background was then subtracted from the W^\pm candidate spectrum to yield the W^\pm signal spectrum (see figure 1). A systematic uncertainty for the background estimation was determined by varying the inverted cuts used to obtain the data-driven background shape and by varying the range where the background shape was normalized to the remaining W^\pm candidate signal.

Preliminary results for the production cross sections and single helicity asymmetries of $W^\pm \rightarrow e^\pm + \nu$ from events with $|\eta| \leq 1$ and $E_T^{2 \times 2} > 25$ GeV can be seen in figures 2 and 3. The measured values are $\sigma(W^+ \rightarrow e^+ + \nu) = 61 \pm 3$ (stat.) $^{+10}_{-13}$ (syst.) ± 14 (lumi.) pb and $\sigma(W^- \rightarrow e^- + \bar{\nu}) = 17 \pm 2$ (stat.) $^{+3}_{-4}$ (syst.) ± 4 (lumi.) pb. The measured asymmetries are $A_L^{W^+} = -0.33 \pm 0.10$ (stat.) ± 0.04 (syst.) and $A_L^{W^-} = 0.18 \pm 0.19$ (stat.) $^{+0.04}_{-0.03}$ (syst.). These

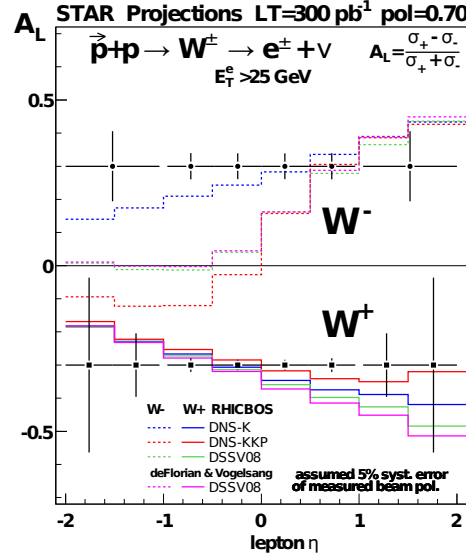


Figure 4. Expected future sensitivities for the single helicity asymmetry for W^\pm production in polarized proton-proton collisions at $\sqrt{s} = 500$ GeV at RHIC. Also plotted are theoretical expectations [4, 5] for a variety of polarized PDFs.

results are consistent with the theoretical calculations using the same acceptance and polarized PDFs which have been constrained by polarized DIS experiments.

3. Future Measurements

In the future, STAR plans to take more data at $\sqrt{s} = 500$ GeV. This data will place a clean constraint on the quark and anti-quark polarized PDFs of the proton. The expected sensitivities for the single helicity asymmetry as a function of pseudorapidity can be seen in figure 4. The calculation in the figure assumed our demonstrated efficiency and background rejection in the mid-rapidity region while in the forward and backward rapidity regions, a worse signal to background ratio was assumed. The uncertainties are for 300 pb^{-1} of sampled luminosity and 70% average polarization which is the the goal of the longitudinal $\sqrt{s} = 500$ GeV spin program at RHIC.

4. Summary

The STAR Collaboration has taken its first data with longitudinally polarized proton beams at $\sqrt{s} = 500$ GeV in 2009. First results on the mid-rapidity cross section and single helicity asymmetry for W^\pm were presented. This opens a new era in the study of the spin-flavour structure of the proton based on the production of W^\pm bosons.

References

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